

NEW CONSIDERATIONS FOR ESTIMATING LUNAR SOIL MATURITY FROM VIS-NIR REFLECTANCE SPECTROSCOPY. T. Hiroi¹, C. M. Pieters¹, and R. V. Morris², ¹Department of Geological Sciences, Brown University, Box 1846, Providence, RI 02912, U. S. A. (Takahiro_Hiroi@brown.edu), ²SN3, NASA Johnson Space Center, Houston, TX 77058, U. S. A.

It is commonly recognized that Vis-NIR reflectance spectra of lunar soils become darker and redder as they are exposed to the space environment until the soils become "mature" where no more significant spectral alteration occurs. Therefore, it is expected that exposure degree of non-mature lunar soils can be estimated in some way by analyzing the effects on reflectance spectra. Estimating exposure degree of lunar soils from their reflectance spectra is important for evaluating their mineral and chemical compositions and determining the exposure history of the lunar regolith.

The maturity (*i.e.*, relative length of surface exposure) can be represented by I_s/FeO , where I_s is the intensity of the ferromagnetic resonance from nanophase metallic iron particles (diameters ≈ 33 nm) and FeO is the weight percent FeO of the soil [1,2]. It has been shown that a positive correlation exists between I_s/FeO and the reflectance ratio between wavelengths shortward and within the 1- μm absorption band for non-mature soils [3,4]. Two similar wavelengths were used to estimate Fe contents of lunar soils [5]. Also, albedo and scaled continuum slopes of lunar soils have been shown to have some correlation with their maturity [3]. However, no quantitatively satisfactory relationship has been identified between a spectral parameter and maturity for both mature and non-mature lunar soils. In this paper, we have evaluated correlations between soil spectral parameters and degree of weathering.

Because maturing process of lunar soils is known to make their spectra darker and redder, the continuum of each lunar soil spectrum is expected to reflect its maturity. Depicted in Fig. 1 are definitions of the spectral parameters used in this study. The 1- μm band continuum is calculated as the tangent line having a slope c_1 and a reflectance-axis cut-off value c_0 . Approximated absorbance c_{0k} for reflectance c_0 (calculated from the Kubelka-Munk function

[6]) and reflectance R_{750} at $0.75 \mu\text{m}$ are also used in this study. These spectral parameters were calculated from reflectance spectra of 35 Apollo bulk lunar soils many of which are used in [3,4]. All spectra were measured at 30° incidence and 0° emergence angles.

Shown in Fig. 2 are the results plotted to show correlation between physical properties (I_s and I_s/FeO) and spectral parameters of the lunar soils. I_s/FeO and FeO values were taken from [7]. Soils from each Apollo missions are shown with different symbols specified in Fig. 2 (a). Three combinations of spectral parameters are plotted as vertical axis: Two kinds of normalized continuum slopes (c_1/R_{750} and c_1/c_0), and approximated absorbance of continuum at 0 wavelength (c_{0k}).

It is clearly seen from Fig. 2 that I_s alone has much better positive correlation with any of the spectral parameters than I_s/FeO , and is applicable to both mature and non-mature soils. Accordingly, when I_s/FeO is used as the horizontal axis in the plots (b), (d), and (f), each Apollo suite seems to have its own profile with different inclination from others depending on its FeO content. When I_s value is used instead of normalizing it by FeO value in plots (a), (c), and (e), the scatter of points is much less than the latter case. The correlation of I_s with c_1/R_{750} is very good for low-intermediate I_s values, but becomes nonlinear at high I_s values (possibly due to differences in chemical/mineral composition other than Fe content such as Ti content). I_s and c_1/c_0 seem to have a positive linear correlation if 10084 is excluded. On the other hand, although I_s and c_{0k} seem to have a more non-linear correlation, a satisfactory line can be fit without excluding any data point and passes the origin.

The above results indicate that spectral effects (changes in continuum spectrum) are in proportion to the absolute amount of nanophase metallic iron (I_s). Physically, this result is reasonable because the concentration of the pigment (nanophase metallic iron) is proportional to I_s and not I_s/FeO .

Because the continuum spectral parameters can thus be used as a measure of I_s , independent spectral parameters proportional to FeO are required to calculate soil maturity from spectral data alone. Previous study in estimating Fe content from reflectance values at two wavelengths shortward and within the 1- μm band [3,5] may be used to restrain FeO content. However, a more precise and physically sound approach is highly desirable, which will probably require complete NIR spectra.

Acknowledgment: All reflectance spectra in this study were measured at RELAB, a multiuser facility located in Brown University and operated under NASA grant NAGW-748. We appreciate S. F. Pratt for helpful suggestions and

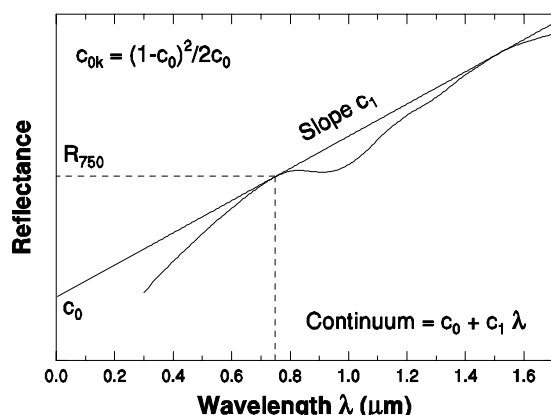


Fig. 1. Definition of the 1- μm band tangent-line continuum and the parameters c_0 , c_1 , c_{0k} , and R_{750} .

programs. Support from NAGW-28 is gratefully acknowledged (CMP).

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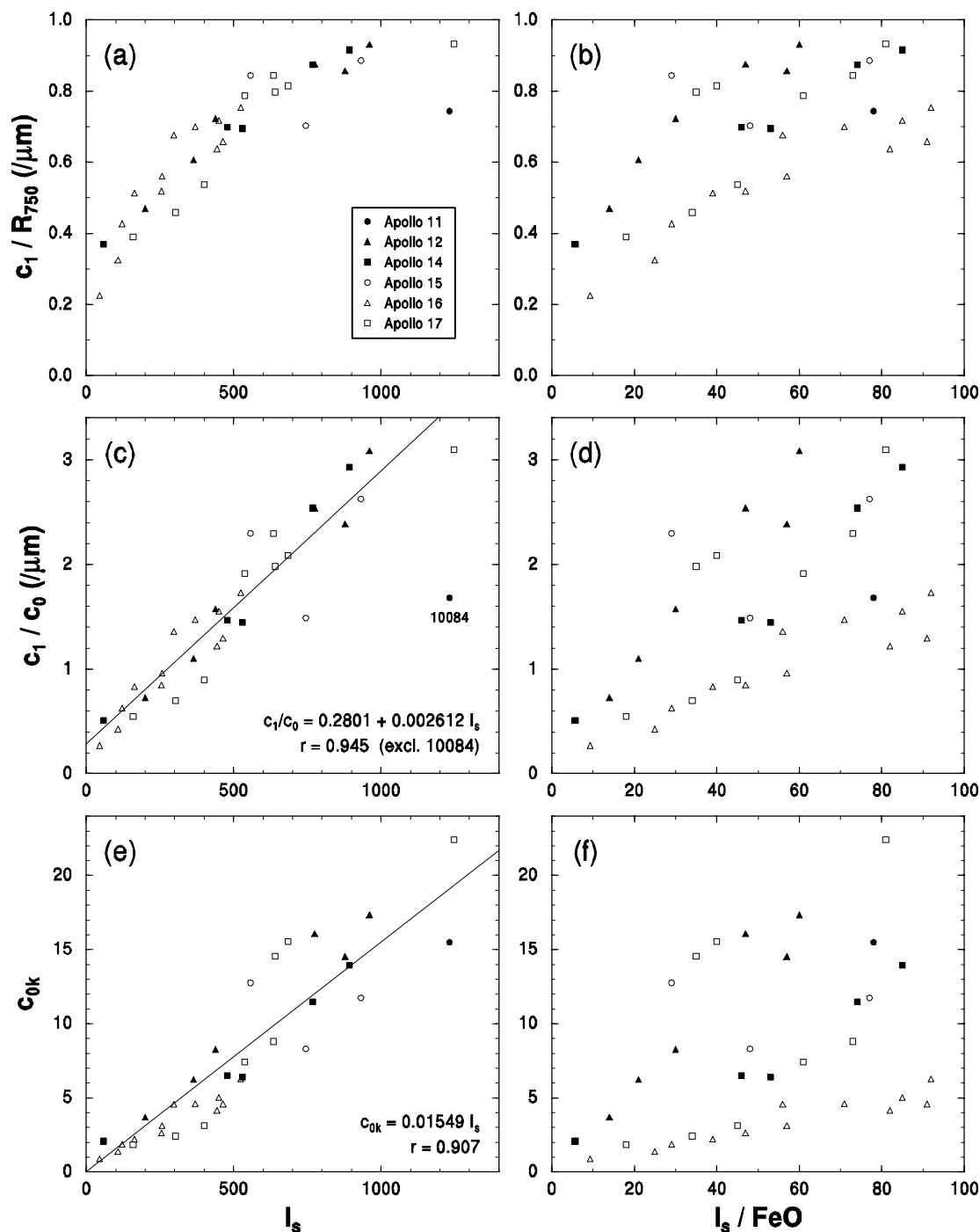


Fig. 2. Correlations between the concentration of nanophase metallic iron (I_s) and surface maturity parameter (I_s/FeO) and three continuum parameters.